NGST integral field spectroscopy at high spectral and spatial resolution

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1. Assumed NGST spectroscopic sensitivity

An L_{AB} = 25.0 source in 0.08 arcsec diameter pixels gives S/N = 5 at R=3000 in the continuum in 4.5 hours. This requires 17 exposures and the light is assumed to be spread over 17 pixels. L_{AB}=25 is 3.81×10^{-33} $Wm^{-2}Hz^{-1}$ in the continuum, equivalent to 9.3×10^{-20} $Wm^{-2}\mu m^{-1}$, so the equivalent line flux at R=3000 is 1.08×10^{-22} Wm^{-2} (or 1.08×10^{-19} erg s^{-1} cm^{-2}).

I consider the following canonical redshifts, z = 1, z =3 and z = 5 (for reference, Hα is at 3.5 microns for z = 4.3). I will consider an $\Omega = 0.2$ $\Lambda = 0$ cosmology with H_0 = 65 $kms^{-1}Mpc^{-1}$, leading to luminosity distances of 6500, 28400 and 58700 Mpc respectively. 1 Mpc is 3.08×10^{22} m, so the line luminosities for S/N = 5 in 4.5 hours at R=3000 are 5.5×10^{31} W, 1.04×10^{33} W and 4.4×10^{33} W respectively.

2. Line and continuum emission from star-forming galaxies

The standard "Kennicutt" relations between Hα luminosity and star-formation rate, and the equivalent for ultraviolet "flat-spectrum" flux density, are:

SFR (M_O yr^{-1}) = 7.9×10^{-35} L(Hα) (W)
SFR (M_O yr^{-1}) = 1.4×10^{-21} L_ν(UV) (W Hz^{-1})

So the line luminosity above corresponds to 0.004, 0.08 and 0.35 M_O yr^{-1} at the three redshifts considered. This is impressively low. The Orion Nebula is XXX

We can now convert a line flux detection limit to an ultraviolet continuum detection limit.

$L_\nu(uv)/L(H\alpha) = 5.6 \times 10^{-14}$ Hz^{-1}

So,

$f_\nu(uv)/f(H\alpha) = 5.6 \times 10^{-14}$ (1+z) Hz^{-1}

A line flux of 1.08×10^{-22} Wm^{-2} therefore corresponds to an ultraviolet flux density of 6.09×10^{-36} (1+z) $Wm^{-2}Hz^{-1}$, or AB = 31.24, 30.48, 30.04 at the three redshifts of interest. This assumes no reddening, which could plausibly add about a magnitude to the ultraviolet continuum.

In terms of the continuum, the $(I\text{-}L)_{AB}$ colour of an Scd galaxy at z = 4 is approximately $(I\text{-}L)_{AB}$ = 3, so the L_{AB} = 25.0 translates to I_{AB} = 28, or 2-3 magnitudes above the

equivalent limit for the line. This makes sense, an R=3000 spectrum boosts the line by EW/λ × R. This is about 15 for a 0.5% equivalent width line (i.e. $EW_0(H\alpha) \sim 30$ Å).

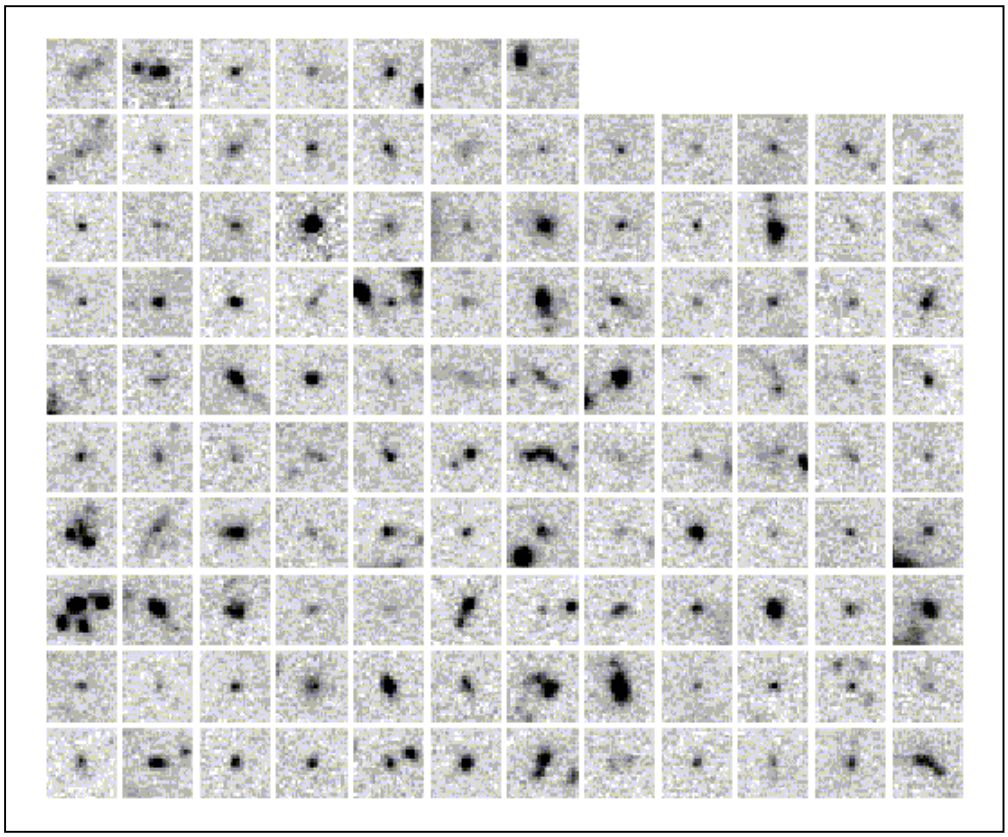
Put more directly, a surface brightness of $L_{AB} = 25.0$ per 0.08 arcsec pixel translates into $\mu_{AB}(L) = 19.5$ mag arcsec^{-2}, equivalent to a rest-frame $\mu_{AB}(R)=14.3$ mag arcsec^{-2} at z = 4. This is remarkably high.

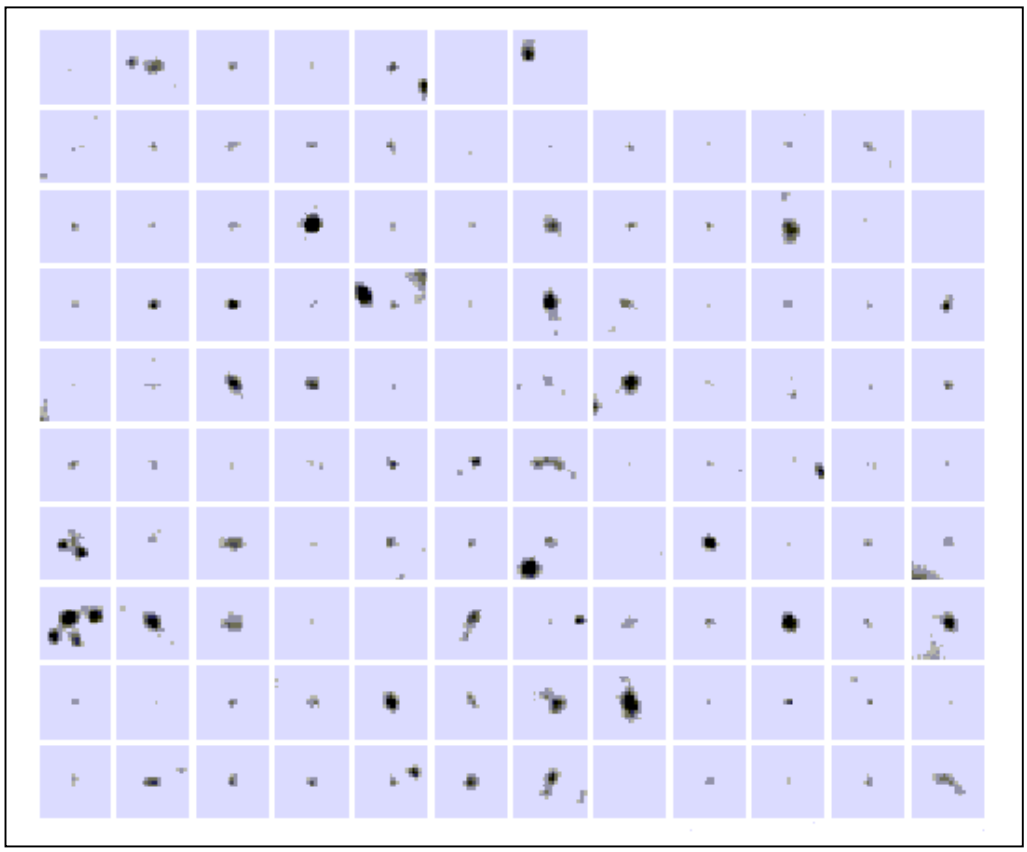
3. What fraction of galaxies at high redshift have detectable extended structure?

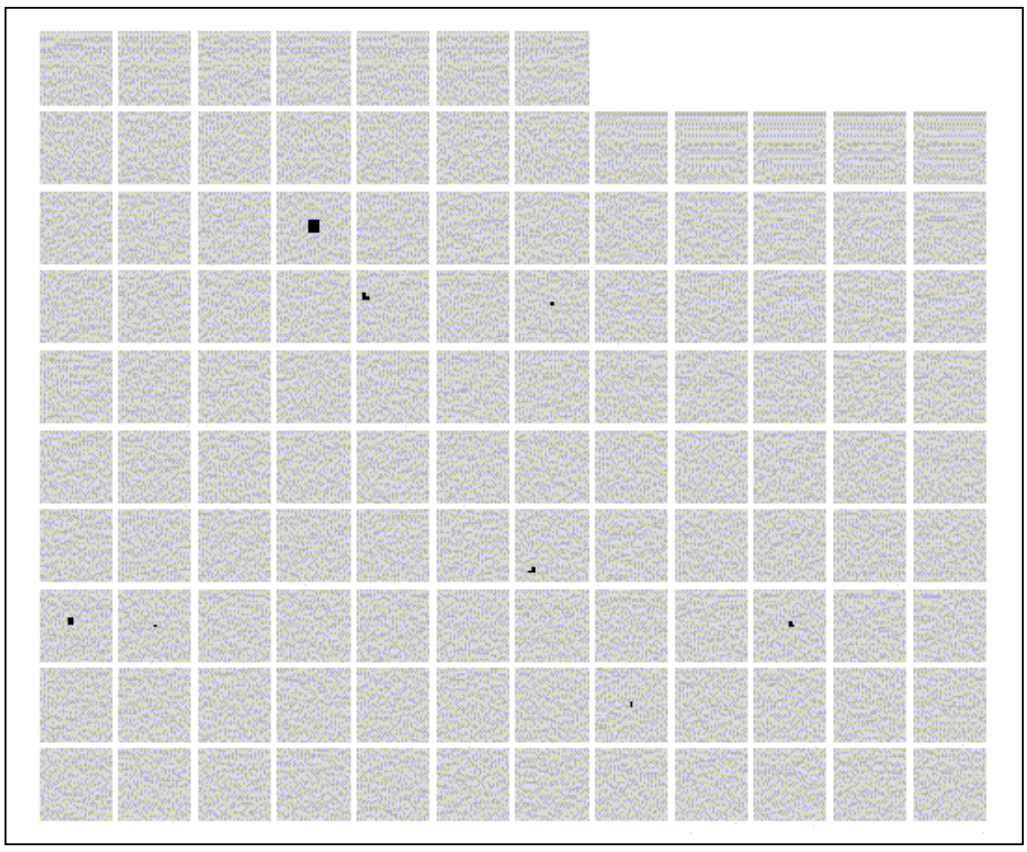
What fraction of the images of $3 < z < 5$ galaxies in the HDF have extended structure above these surface brightness thresholds *at the same spatial resolution*? Using the standard HDF calibration, the three effective line surface brightness limits correspond to 0.00021, 0.0004, 0.0006 counts per 0.08 arcsec pixel, while the equivalent continuum limit is 0.004 counts per 0.08 arcsec pixel.

The following three figures show the 115 galaxies in the HDF with spectroscopic or photometric redshifts in the $3 < z < 5$ range, with no surface brightness cut, and then with surface brightness cuts applied at 0.0004 counts/0.08" pixel (representing the line sensitivity) and 0.004 counts/0.08" pixel (representing the continuum).

Three mosaics of F814W images of 115 HDF galaxies with 3 < z <6, showing (tot) all surface brightnesses, (middle) surface brightnesses equivalent to the Hα detection threshold and (bottom) surface brightnesses equivalent to the continuum detection threshold, all at R=3000. Boxes are 2 arcsec to a side.







4. Summary

The conclusion is that while the continuum surface brightness limit is a real problem – almost no objects have an extended continuum surface brightness above the level of detectability in high spatial/high spectral spectroscopy, the factor of ten that you gain with plausible line emission is sufficient to bring extended structure in many objects above the threshold.